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Reference Data

^{1}H and ^{13}C Chemical Shifts of some Bicyclo[4.3.0]- and Bicyclo[6.3.0)-γ-lactones and α-Carbomethoxy-γ-lactones

Laurent Lamarque,[1] Mylène Campredon,[1] Alain Méou,[1] Pierre Brun[1]* and Robert Faure[2]

[1] ERS CNRS 158, Université de la Méditerranée, 163 Avenue de Luminy, 13288 Marseille Cédex 9, France
[2] ESA CNRS 1411, Université d'Aix-Marseille III, Avenue Escadrille Normandie-Niemen, 13397 Marseille Cédex 20, France

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ABSTRACT: The ^{1}H and ^{13}C NMR resonances of ten bicyclo[4.3.0]- and bicyclo[6.3.0]-γ-lactones and α-carbomethoxy-γ-lactones were completely and unambiguously assigned by a combination of homonuclear (gs-COSY), ^{1}H-detected heteronuclear one-bond (gs-HMQC) and long-range (gs-HMBC) gradient-selected correlation experiments. © 1998 John Wiley & Sons, Ltd.

KEYWORDS: NMR; ^{1}H NMR; ^{13}C NMR; gs-2D NMR; bicyclo[4.3.0]-γ-lactones, bicyclo[6.3.0]-γ-lactones, α-carbomethoxy-γ-lactones

INTRODUCTION

α-Methylene-γ-lactones are present in a large variety of natural products and exhibit interesting biological properties.[1] These compounds can be easily synthesized in two steps from either γ-lactones or α-carbomethoxy-γ-lactones.[2] In this paper, we report the complete ^{1}H and ^{13}C NMR chemical shift assignments obtained from one- and gradient-selected two-dimensional NMR techniques for five γ-lactones and five α-carbomethoxy-γ-lactones (Fig. 1).

RESULTS AND DISCUSSION

The ^{13}C and ^{1}H chemical shifts for compounds **1**–**10** are presented in Tables 1–3 and selected proton–proton coupling constants in Table 4.

The ^{1}H and ^{13}C chemical shifts of the five-membered ring atoms for **1**–**10** were identified in a straightforward manner using chemical shift considerations and concerted application of DEPT, COSY and HMQC experiments. However, complete determination of NMR spectral data for the six- and eight-membered ring atoms cannot be achieved on the basis of the above techniques since, even at 400 MHz, strongly coupled spin systems are present. Therefore, utilization of HMBC diagrams proved particularly helpful for the assignments of the various diastereotopic methylene groups. Unfortunately, for **5** and **10**, the isochronous resonances of ethylenic protons preclude the unambiguous identification of the corresponding sp^2-hybridized carbons.

For the α-carbomethoxy-γ-lactones **6**–**10**, the distinction between the two carbonyl functions was realized unequivocally from the long-range correlation peaks observed between methoxy protons and carbonyl ester carbon. For all the compounds, it should be noted that the carbonyl ester resonance was more deshielded than the lactone group signal. This observation is opposite to previously reported results.[3]

Moreover, the stereochemistry of **6**–**10** was established using phase-sensitive NOESY experiments; the proposed structures (Fig. 1) were in fair agreement with the x-ray spectroscopic results.[4] Finally, the assignment of diastereotopic methylene protons in position 2 for **1**–**5** was achieved from the magnitude of the ^3J(H-2,H-3) coupling constants and by comparison of these values with the corresponding values for **6**–**10**.

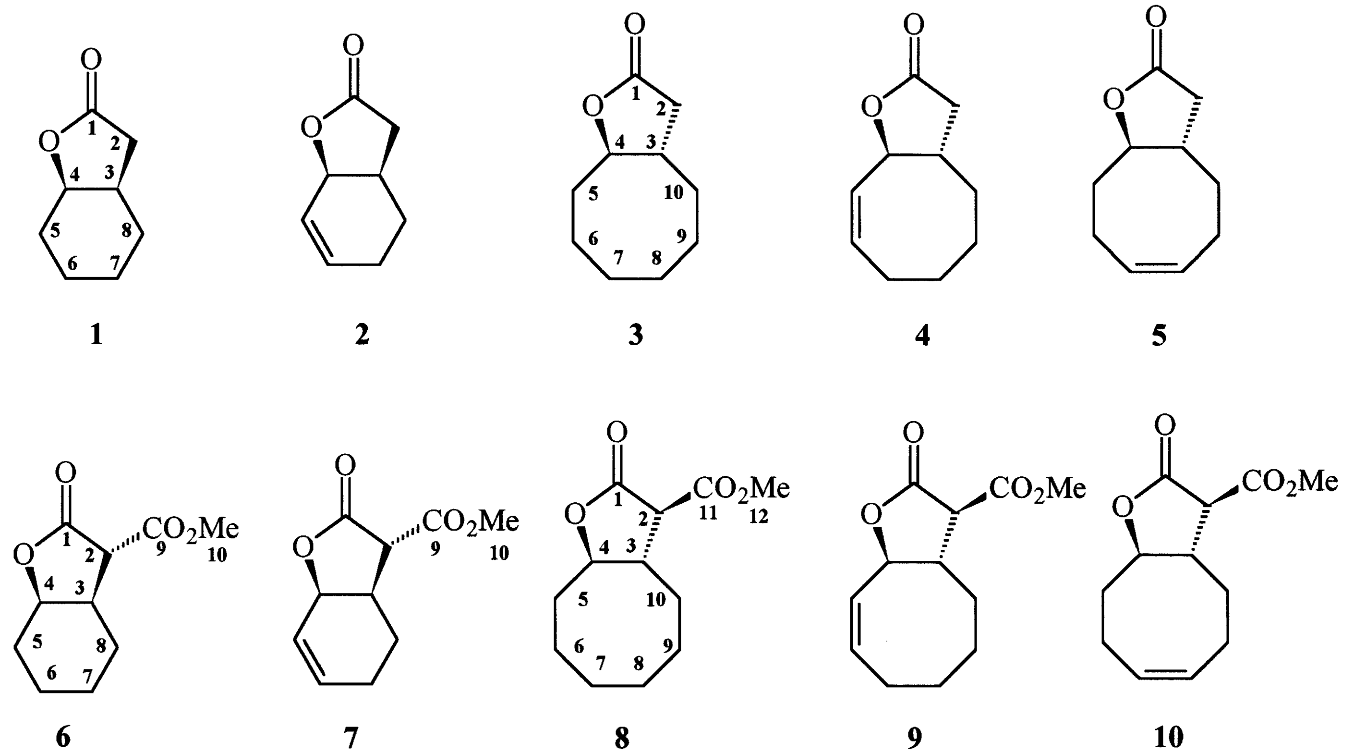

Figure 1. Structures of γ-lactones **1**–**10**.

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* *Correspondence to*: P. Brun, ERS CNRS 158, Université de la Mediterranée, 163 Avenue de Luminy, 13288 Marseille Cédex 9, France.
E-mail address: brun@chimlum.univ-mrs-fr

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Table 1. ^{13}C NMR chemical shifts of γ-lactones **1–10**[a]

Atom	1	2	3	4	5	6	7	8	9	10
C-1	177.60	176.95	176.03	176.17	176.20	167.84	167.95	168.18	167.78	168.16
C-2	37.46	35.06	38.13	36.87	36.91	53.12	51.34	55.50	53.86	54.62
C-3	34.82	33.50	40.57	46.79	39.84	39.07	37.93	44.85	50.15	44.30
C-4	79.15	75.53	86.54	83.42	85.89	78.36	75.16	84.94	81.62	84.36
C-5	27.74	123.16	34.91	129.27	33.63	28.03	123.22	34.39	128.92	33.38
C-6	19.86	134.15	24.40	129.85	21.26	20.32	133.62	24.22	130.05	21.12
C-7	22.76	22.65	21.97	24.99	129.58[b]	21.98	21.61	21.90	24.97	129.59[b]
C-8	27.12	23.48	26.73	27.89	129.69[b]	26.22	22.34	26.61	27.76	129.66[b]
C-9	—	—	27.37	23.93	24.26	172.09	171.35	27.28	23.62	24.04
C-10	—	—	34.51	27.85	32.38	52.94	53.04	33.35	27.03	31.84
C-11	—	—	—	—	—	—	—	170.60	171.06	170.68
C-12	—	—	—	—	—	—	—	52.98	52.96	53.05

[a] In ppm from TMS; $CDCl_3$ as solvent.
[b] Assignments may be reversed.

EXPERIMENTAL

Materials

Compounds **1**–**5** and **6**–**10** were prepared by the addition of acetic acid and potassium monomethylmalonate respectively, to alkenes, promoted by $Mn(OAc)_3$.[2] The products were purified by flash chromatography. All new compounds gave satisfactory elemental analyses (C, H, O).

NMR spectra

All experiments were performed in 5 mm tubes on a Bruker AMX-400 spectrometer in $CDCl_3$ solutions and tetramethylsilane (TMS) was used as an internal standard. Proton coupling constants were extracted from the resolution-enhanced ^1H spectrum using the Gaussian multiplication technique.[5] Resonance multiplicities for ^{13}C were established via the acquisition of DEPT spectra.[6] For the DEPT sequence, the width of a ^{13}C 90° pulse was 4.5 μs, that of a ^1H 90° pulse was 10 μs and the $(2J)^{-1}$ delay was set at 3.4 ms. For two-dimensional experiments, an inverse probehead incorporating a shielded *Z*-gradient was used. The gradients were amplified by a Bruker B-AFPA-10 amplifier.

gs-COSY spectra were obtained using a pulse sequence (cosy11gs in the operating Bruker software) which includes a 1:1 gradient combination.[7] The spectral widths were 10 ppm and the spectra were collected as 1K × 256 blocks of data. Zero filling was applied in F_1 in order to have a symmetrical matrix of 512 × 512 real data points,

Table 2. ^1H NMR chemical shifts of γ-lactones **1–5**[a]

Atom	1	2	3	4	5
H-2	2.17 (α), 2.56 (*β*)	2.27 (α), 2.66 (*β*)	2.26 (α), 2.73 (*β*)	2.24 (α), 2.56 (*β*)	2.30 (α), 2.73 (*β*)
H-3	2.34	2.53	2.41	2.11	2.43
H-4	4.45	4.74	4.43	4.92	4.36
H-5	1.62, 2.00	5.81	1.65, 2.20	5.83	1.53, 2.21
H-6	1.40	6.08	1.43, 1.79	5.64	2.17, 2.34
H-7	1.19, 1.53	1.98, 2.05	1.41, 1.83	2.07, 2.20	5.68
H-8	1.15–1.67	1.42, 1.68	1.32, 1.84	1.28, 1.95	5.68
H-9	—	—	1.45, 1.65	1.36, 1.78	2.21
H-10	—	—	1.41, 1.95	1.62, 1.67	1.40, 1.93

[a] In ppm from TMS; $CDCl_3$ as solvent.

Table 3. ^1H NMR chemical shifts of α-carbomethoxy-γ-lactones **6–10**[a]

Atoms	6	7	8	9	10
H-2	3.36	3.42	3.32	3.32	3.36
H-3	2.81	3.03	2.81	2.51	2.84
H-4	4.73	5.03	4.43	4.96	4.38
H-5	1.83	5.84	1.80, 2.23	5.84	1.64, 2.29
H-6	1.40, 1.48	6.10	1.43, 1.79	5.69	2.18, 2.40
H-7	1.36, 1.57	1.60, 1.82	1.58, 1.86	2.20	5.71
H-8	1.40, 1.73	2.11, 2.16	1.29, 1.79	1.66	5.71
H-9	—	—	1.49, 1.79	1.39, 1.84	2.22
H-10	3.79	3.82	1.49, 2.00	1.32, 1.94	1.46, 1.97
H-12	—	—	3.82	3.82	3.82

[a] In ppm from TMS; $CDCl_3$ as solvent.

Table 4. ^1H–^1H coupling constants (Hz) for γ-lactones **1–10**

Coupling constant	Pair of protons	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
^2J	2α–2β	−16.6	−16.8	−16.6	−16.1	−16.8	—	—	—	—	—
^3J	2α–3	2.5	3.6	11.1	11.9	10.8	—	—	11.4	12.8	11.0
	2β–3	6.8	8.1	8.0	6.7	8.6	5.5	6.5	—	—	—
	3–4	4.1	4.1	9.0	9.9	8.1	5.3	6.2	7.9	10.6	8.5
	3–10α	—	—	11.0	—	10.8	—	—	10.9	10.7	10.5
	3–10β	—	—	3.9	—	3.9	—	—	3.8	2.7	3.5
	4–5α	4.1	3.7	4.6	5.9	3.9	5.3	3.3	8.0	5.8	4.0
	4–5β	8.2	—	9.0	—	10.7	10.6	—	4.6	—	10.6
^4J	4–6		0.5		1.7					1.2	

which was processed in each dimension by unshifted sinusoidal windows.

The gs-HMQC spectra (inv4gs in the Bruker software) resulted from a 1024 × 128 data matrix size with 4–16 scans per t_1 depending on the sample concentration, an inter-pulse delay of 3.5 ms and a 5:3:4 gradient combination.[8] gs-HMBC spectra were acquired using a pulse sequence (hmbcgs in the Bruker library) optimized on ^2J or ^3J couplings (inter-pulse delay for the evolution of long-range couplings: 50 ms) and the same gradient ratio as described above for HMQC experiments.[9] In this way, direct responses (^1J couplings) were not completely removed. Finally, NOESY spectra were recorded using a phase-sensitive mode experiment[10] (noesytp in the Bruker software) and the same parameters as indicated above for COSY diagrams.

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